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(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 916 500 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
19.05.1999 Bulletin 1999/20

(51) Int. Cl.[6]: B41J 2/16

(21) Application number: 98309372.5

(22) Date of filing: 16.11.1998

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 17.11.1997 JP 315267/97

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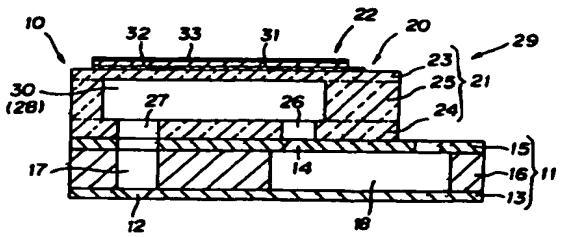
(54) Heat treatment method of actuators for an ink jet printer head and method for manufacturing an ink jet printer head

(57) An actuator 20 is prepared which comprises an ink pump section 29 made by forming a spacer plate 25 with a plurality of window portions 28 formed thereon, a closure plate 23 stacked on one side of the spacer plate 25 for covering the window portions 28 and a connection plate 24 stacked on the other side of the spacer plate 25 for covering the above window portions 28 respectively of ceramic green sheets in lamination to integrally fire them, and a piezoelectric/electrostrictive operating section 22 composed of electrodes 31, 33 and a piezoelectric/electrostrictive layer 32 on the outer surface of the closure plate 23. Thereafter, the actuator 20 is pasted to a holding adhesive film and the holding adhesive film is stripped from the actuator 20 after subjecting the actuator to a given inspection if necessary or to cutting into a given shape if necessary. Subsequently the actuator 20 is heat-treated. Then, onto this actuator 20, an ink nozzle member 11 with a plurality of nozzle holes 12 is stacked and joined. The ink jet print head has a strong joining and an improvement in liquid resistance.

Fig.1



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Description

Background of the Invention and Related Art Statement

[0001] The present invention relates to a heat treatment method of actuators for an ink jet printer heads and method for manufacturing an ink jet printer head.

[0002] As shown in Figs. 1 and 2, the ink jet printer head is so constructed by integrally joining a piezoelectric/electrostrictive film type chip 10 into which a plurality of actuators 20 are integrated and an ink nozzle member 11 with a plurality of nozzle holes 12 opened corresponding to the individual actuators 20 that the ink supplied into the pressure chamber 30 formed in an actuator 20 is jetted through its nozzle hole 12.

[0003] The ink nozzle member 11 is constructed by laminating a thin planar nozzle plate 13 provided with a plurality of nozzle holes 12 and a similarly thin planar orifice plate 15 provided with a plurality of orifice holes 14, with a flow path plate 16 interposed therebetween to integrally join them with an adhesive or the like. Inside the ink nozzle member 11, an ink jet pass 17 for leading ink to nozzle holes 12 and an ink supply flow paths 18 for leading ink to orifice holes 14 are formed. Incidentally, these ink nozzle members 11 are normally made of metal or plastics.

[0004] An actuator 20 comprises a ceramic substrate 21 and a piezoelectric/electrostrictive operating section 22 integrally formed on the ceramic substrate 21. The ceramic substrate 21 is integrally composed a thin planar closure plate 23 and a thin planar connection plate 24 stacked together with a spacer plate 25 interposed therebetween to form an ink pump section 29. Incidentally, these closure plate 23, connection plate 24 and spacer plate 25 are respectively formed of ceramic green sheets by lamination and integrally fired to make an ink pump section. Here, in the connection plate 24, a first communicative opening 26 and a second communicative opening 27 are formed at the respective positions corresponding to the orifice hole 14 formed on an orifice plate 15 of an ink nozzle member 11.

[0005] In the spacer plate 25, a plurality of window sections 28 are formed, while a spacer plate 25 and a connection plate 24 are stacked together so as to allow the first communicative opening 26 and a second communicative opening 27 provided on the connection plate 24 to be opened against each window section 28. Besides, on the side opposed to the stacked one of the spacer plate 25 with the connection plates 24, the closure plate 23, with which the opening of the window section 28 is covered.

[0006] In this manner, the pressure chamber 30 is formed inside this ceramics substrate 21.

[0007] And, on the outer surface of the closure plate 23 in the ceramic substrate 21, the respective piezoelectric/electrostrictive operating sections 22 are provided at the sites corresponding to individual pressure chambers 30. Here, a piezoelectric/ electrostrictive operating sections 22 comprises a lower electrode 31, a piezoelectric/electrostrictive layer 32 and an upper electrode 33.

[0008] As described above, the ink jet printer head comprises an actuator made of ceramics body and an ink nozzle member, both of which are normally joined by using an adhesive.

[0009] When an actuator and an ink nozzle member are joined by using an adhesive like this to manufacture an ink jet printer head, however, there has frequently occurred a situation that the actuator and the ink nozzle member are stripped off each from other under action of ink at the time of use. As a result of investigation into this situation, the present inventor found that this originated in slight traces of adhesive remaining in the actuator.

[0010] Namely, after prepared as a piezoelectric/electrostrictive film type chip 10 in which a plurality of actuators 20 are int grated as shown in Fig. 2, an actuator is adhered to a holding adhesive film such as dicing film and subjected to a given inspection if necessary to clarify whether or not the actuator 20 manifests a desired performance or the like. And, after the inspection, the adhesive film is striped if necessary from an actuator cut in a given shape and then the actuator is joined to an ink nozzle member via an adhesive. However, it became clear that slight traces of adhesive of the adhesive film remained in the actuator at the time of stripping an adhesive film from the actuator, which resulted in damages to the adhesive effect of an adhesive between the actuator and the ink nozzle member.

Summary of the Invention

[0011] As a result of various examinations for a removal of traces of adhesive remaining in an actuator, the present inventor found that heat treatment at a given temperature was effective for a removal of the adhesive and effective for the peeling of the actuator from an ink nozzle member under action of ink and accordingly reached the present invention.

[0012] According to the present invention, there is provided a heat treatment method of actuators for an ink jet printer head comprising the steps of preparing an actuator comprising: an ink pump section made by integral firing of a spacer plate with a plurality of window portions formed thereon, a closure plate stacked on one side of the spacer plate for covering the above window portions and a connection plate stacked on the other side of the spacer plate for covering the above window portions formed respectively of ceramic green sheets by lamination; and a piezoelectric/ electrostrictive operating section composed of electrodes and a piezoelectric/electrostrictive layer on the outer surface of the closure

plate, thereafter pasting the actuator onto a holding adhesive film, stripping the holding adhesive film from the actuator after subjecting the actuator to a given inspection if necessary or to cutting into a given shape if necessary and subsequently heat treating the actuator.

[0013] In the present invention, the heat treatment of an actuator is carried out preferably at temperatures or higher where the weight reduction stops in the thermogravinometric (TG) analysis or the decomposition or combustion of an adhesive ends.

[0014] Besides, in the present invention, the heat treatment of an actuator is carried out preferably by maintaining the treating temperature for more than 10 min. at temperatures or higher where the weight reduction stops in the TG analysis, as seeing from the result shown in Table 1 mentioned below. Since maintaining the temperature for more than 10 min. in the atmosphere leads to a complete removal of the residual carbon after the combustion of an adhesive or a scattering of the moisture adsorbed on the actuator surface, the adhesion is stabilized. More preferably in the heat treatment of an actuator, it is desired to maintain the temperature for more than 30 min. However, these maintained periods mean preferable ones near higher temperatures than the above one (temperature where the weight reduction stops in the TG analysis) as heat treatment temperatures. If heat treatment is carried out at a considerably higher temperature than the above one (temperature where the weight reduction stops in the TG analysis), its effect increases and consequently an equivalent effect can be expected even for a shorter maintained period.

[0015] Furthermore, according to the present invention, there is provided a method for manufacturing an ink jet printer head comprising the steps of preparing an actuator comprising: an ink pump section made by integral firing of a spacer plate with a plurality of window portions formed thereon, a closure plate stacked on one side of the spacer plate for covering the above window portions and a connection plate stacked on the other side of the spacer plate for covering the above window portions formed respectively of ceramic green sheets by lamination; and a piezoelectric/electrostrictive operating section composed of electrodes and a piezoelectric/ electrostrictive layer on the outer surface of the above closure plate, thereafter pasting the actuator onto a holding adhesive film, stripping the holding adhesive film from the actuator after subjecting the actuator to a given inspection if necessary or to cutting into a given shape if necessary, subsequently heat-treating the actuator and then stacking and joining an ink nozzle member with a plurality of nozzle holes to the actuator.

[0016] In the present invention, it is preferred to joining the actuator and the ink nozzle member with an adhesive interposed therebetween and in this case it is preferred to use a thermosetting resin adhesive as the adhesive.

[0017] Besides, in view of improvement in liquid resistance as resistance to ink, it is preferable that the junction surface to the nozzle has a surface roughness Ra of 0.05 to 0.25 μm because of enhancing the adhesive strength and further increasing the interface distance A between the adhesive 1 and the actuator surface 2 as shown in Fig. 4.

Brief Description of the Drawings

[0018]

Fig. 1 is a sectional view showing one example of actuator.
Fig. 2 is a plan illustration showing one example of piezoelectric/electrostrictive film type chip.
Fig. 3 is a graph showing the TG analysis data of actually used adhesives.
Fig. 4 is an illustration showing the interfacial distance between the adhesive and the actuator surface.

Detailed Description of Preferred Embodiment

[0019] The present invention is featured by heat-treating an actuator before joining the actuator and an ink nozzle member. Namely, an actuator is prepared which comprises an ink pump section made by laminatedly forming a spacer plate and a closure plate and a connection plate respectively of ceramic green sheets and integrally firing them with a spacer plate interposed therebetween and a piezoelectric/electrostrictive operating section composed of electrodes and a piezoelectric/ electrostrictive layer on the outer surface of the above closure plate. Then, the actuator is pasted onto a holding adhesive film and the holding adhesive film is stripped from the actuator after subjecting the actuator to a given inspection if necessary or to cutting into a given shape if necessary. At this time, traces of adhesive of the adhesive film remains on the adhesion surface of the adhesive film in the actuator even after stripping the adhesive film. Thus, in the present invention, the actuator after stripping the adhesive film is heat-treated.

[0020] For a combustive removal or scattering of the adhesive remaining in an actuator, any heat treatment method may be adopted, but generally it is advisable to maintain an actuator for more than a given period of time at a given temperature or higher preferably for more than 30 min. during the heat treatment because of enabling the adhesive to be removed simply and surely.

[0021] According to experiments of the present inventor, it was confirmed that, if the temperature where the weight reduction of the adhesive stops was found to be 500°C on the TG analysis, the adhesive can be combustively removed

or scattered by the heat treatment at a temperature of 500°C or higher in the atmosphere and no such problems as stripping occurs in the case of subsequently joining the actuator and an ink nozzle member by using a thermosetting resin adhesive. Fig. 3 is a graph showing an example of the temperature where the weight reduction of the adhesive stops being 500°C, based on TG analysis data of the actually employed adhesive.

[0022] In the present invention, there is no special restriction on adhesives employed for joining an actuator and an ink nozzle member, but the type of adhesives employed differs with the material of an ink nozzle member for a ceramic actuator. As ink nozzle members, those made of metal or plastics such as SUS may be used, whereas it is desired as adhesives to employ thermosetting resin adhesives such as polyester, polyamide, nylon, ethylene- acetic-vinyl, polyolefine, urethane and polyethylene for joining.

[0023] Besides, if the ink nozzle member is made of ceramics, it is preferable to employ a ceramic adhesive similar in material to the constituent of an actuator.

[0024] Furthermore, it is desired from the viewpoint of adhesion strength that the junctional surface of an actuator is somewhat rough rather than smooth. To be specific, the junctional surface of an actuator has a surface roughness Ra of preferably 0.05 to 0.25 μm and more preferably 0.07 to 0.25 μm because of enhancing the adhesion strength and further increasing the interface distance between the adhesive and the actuator surface, thus promoting the liquid resistance as resistance to ink.

[0025] It is desired that the junctional surface of an actuator has a surface roughness of not more than 0.25 μm, since adhesion strength reduces due to entrainment of bubble into the junctional interface when the junctional surface is too rough beyond said range.

Examples

[0026] Hereinafter, referring to the examples, the present invention will be described in further detail.

(Example 1)

[0027] To manufacture an ink jet printer head having the configuration shown in Fig. 1, the piezoelectric/electrostrictive film type chip 10 of Fig. 2 with a plurality of actuators 20 integrated was prepared..

[0028] Next, after pasting this piezoelectric/electrostrictive film type chip to a dicing film (adhesive film) by using an adhesive of acryl resin and urethane resin, the dicing film was stripped from the piezoelectric/electrostrictive film type chip (actuator) and subjected to heat treatment. The heat treatment conditions were chosen as shown in Table 1. Incidentally, in Table 1, belt and batch signify those heat-treated in a belt furnace and in a batch furnace, respectively.

[0029] After the heat treatment, each actuator was cut out from the piezoelectric/electrostrictive film type chip and stacked on and joined to an ink nozzle member with a thermosetting resin adhesive (softening point: 100°C) interposed therebetween. On the obtained ink jet printer head, a liquid resistance test was made.

[0030] In the liquid resistance test, the quality was judged by checking the ink leakage with the ink jet printer head dipped in an ink liquid at a given temperature for a given period of time. The result is shown in Table 1.

[Table 1]

No.	Heat Treatment Conditions			Liquid Resistance Test Conditions		Liquid Resistance Test Result	Judgment
	Temperature (°C)	Time (min.)	Method	Temperature (°C)	Time (hr)		
1	530	10	belt	60	120	4/5	X
2	530	30	belt	60	120	1/5 (small leakage)	△
3	530	50	belt	60	120	0/5	○
4	550	30	belt	60	120	1/5	△
5	550	50	belt	60	120	0/5	○
6	570	30	belt	60	120	0/5	○
7	570	50	belt	60	120	0/5	○

[Table 1] (continued)

No.	Heat Treatment Conditions			Liquid Resistance Test Conditions		Liquid Resistance Test Result	Judgment
	Temperature (°C)	Time (min.)	Method	Temperature (°C)	Time (hr)		
8	600	30	belt	60	120	0/5	○
9	500	10	batch	60	120	4/5	X
10	500	30	batch	60	120	1/5 (small leakage)	△
11	500	60	batch	60	120	0/5	○
12	450	60	batch	60	120	4/5	X

[0031] As evident from the result shown in Table 1, it was confirmed that the residual adhesive derived from the pasting of a dicing film was completely removed by the heat treatment at a temperature of 500°C or higher for a period of time above 30 min. in the atmosphere, thus fully manifesting an adhesion effect of the adhesive.

(Example 2)

[0032] After the an hour heat treatment at 550°C in the atmosphere as with Example 1 by using a piezoelectric/electrostrictive film type chip (actuator) varied in the surface roughness Ra of the junctional surface with an ink nozzle member as shown in Table 2, the ink nozzle member was joined to obtain ink jet print heads.

[0033] On these print heads, a liquid resistance test was made as with Example 1. The result is shown in Table 2.

[0034] Incidentally, the surface roughness Ra was measured with the aide of Form Talysurf-120 of Rank Taylor Bobson Co. Ltd.

[Table 2]

No.	Surface Roughness Ra (μm)	Liquid Resistance Test Conditions		Liquid Resistance Test Result	Judgment
		Temperature (°C)	Time (hr)		
13	0.03	60	120	1/5	△
14	0.03	60	120	0/5	○
15	0.04	60	120	1/10	△
16	0.04	60	120	0/10	○
17	0.05	60	120	0/5	○
18	0.05	60	120	0/5	○
19	0.07	60	120	0/5	○
20	0.10	60	120	0/5	○
21	0.20	60	120	0/5	○
22	0.25	60	120	0/5	○

[0035] From Table 2, it is revealed that the liquid resistance to ink was improved if the junctional surface of an actuator has a surface roughness Ra of 0.05 to 0.25 μm. On the other hand, it is also revealed that the liquid resistance to ink somewhat deteriorated if the junctional surface of an actuator has a surface roughness Ra of less than 0.05 μm.

[0036] As described above, according to the present invention, the holding adhesive film is stripped and a piezoelectric/ electrostrictive film type chip (actuator) is subjected to heat treatment prior to the joining to an ink nozzle member, thereby having an advantage that a strong joining is obtained and the liquid resistance is also improved. Thus, the ink

jet print head obtained according to the present invention is excellent in durability.

Claims

1. A heat treatment method of actuator for an ink jet printer head comprising the steps of

   preparing an actuator comprising: an ink pump section made by integral firing of a spacer plate with a plurality of window portions formed thereon; a closure plate stacked on one side of the spacer plate for covering said window portions and a connection plate stacked on the other side of the spacer plate for covering said window portions formed respectively of ceramic green sheets by lamination; and a piezoelectric/electrostrictive operating section composed of electrodes and a piezoelectric/electrostrictive layer on the outer surface of the closure plate,
   thereafter pasting the actuator onto a holding adhesive film,
   stripping the holding adhesive film from the actuator after subjecting the actuator to a given inspection if necessary or to cutting into a given shape if necessary and
   subsequently heat-treating the actuator.

2. A heat treatment method as set forth in claim 1, wherein the heat treatment is carried out at temperature or higher where the weight reduction stops in the thermogravinometric (TG) analysis.

3. A heat treatment method as set forth in claim 1, wherein the heat treatment is carried out by maintaining the treating temperature for more than 10 min. at temperature or higher where the weight reduction stops in the thermogravinometric (TG) analysis.

4. A method for manufacturing an ink jet print head comprising the steps of

   preparing an actuator comprising: an ink pump section made by integral firing of a spacer plate with a plurality of window portions formed thereon, a closure plate stacked on one side of the spacer plate for covering said window portions and a connection plate stacked on the other side of the spacer plate for covering said window portions formed respectively of ceramic green sheets by lamination; and a piezoelectric/electrostrictive operating section composed of electrodes and a piezoelectric/electrostrictive layer on the outer surface of said closure plate,
   thereafter pasting the actuator onto a holding adhesive film,
   stripping the holding adhesive film from the actuator after subjecting the actuator to a given inspection if necessary or to cutting into a given shape if necessary,
   subsequently heat-treating the actuator and then
   stacking and joining an ink nozzle member with a plurality of nozzle holes to the actuator.

5. A method for manufacturing an ink jet print head as set forth in claim 4, wherein the actuator and the ink nozzle member are joined with a thermosetting resin adhesive interposed therebetween.

6. A method for manufacturing an ink jet print head as set forth in claim 4, wherein the heat treatment is carried out by maintaining the treating temperature for more than 10 min. at temperatures or higher where the weight reduction stops in the thermogravinometric (TG) analysis.

7. A method for manufacturing an ink jet print head as set forth in any one of claims 4 to 6, wherein the junction surface has a surface roughness Ra of 0.05 to 0.25 μm.

Fig.1

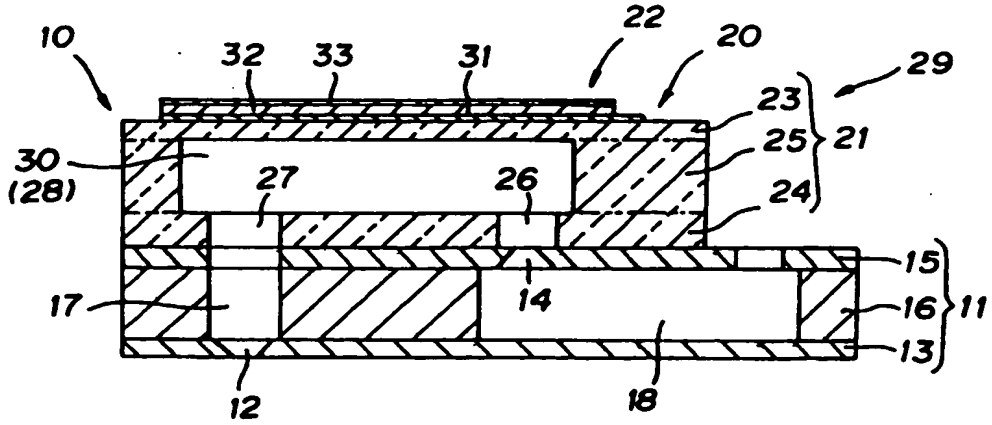


Fig.2

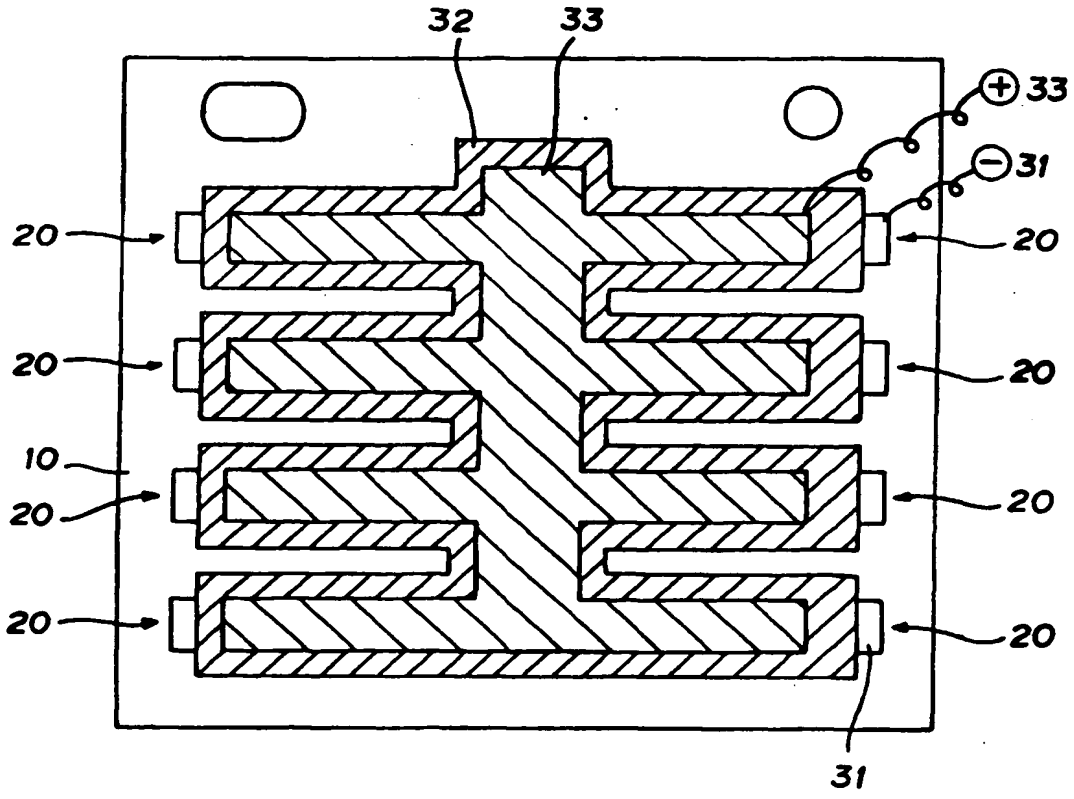


Fig.3

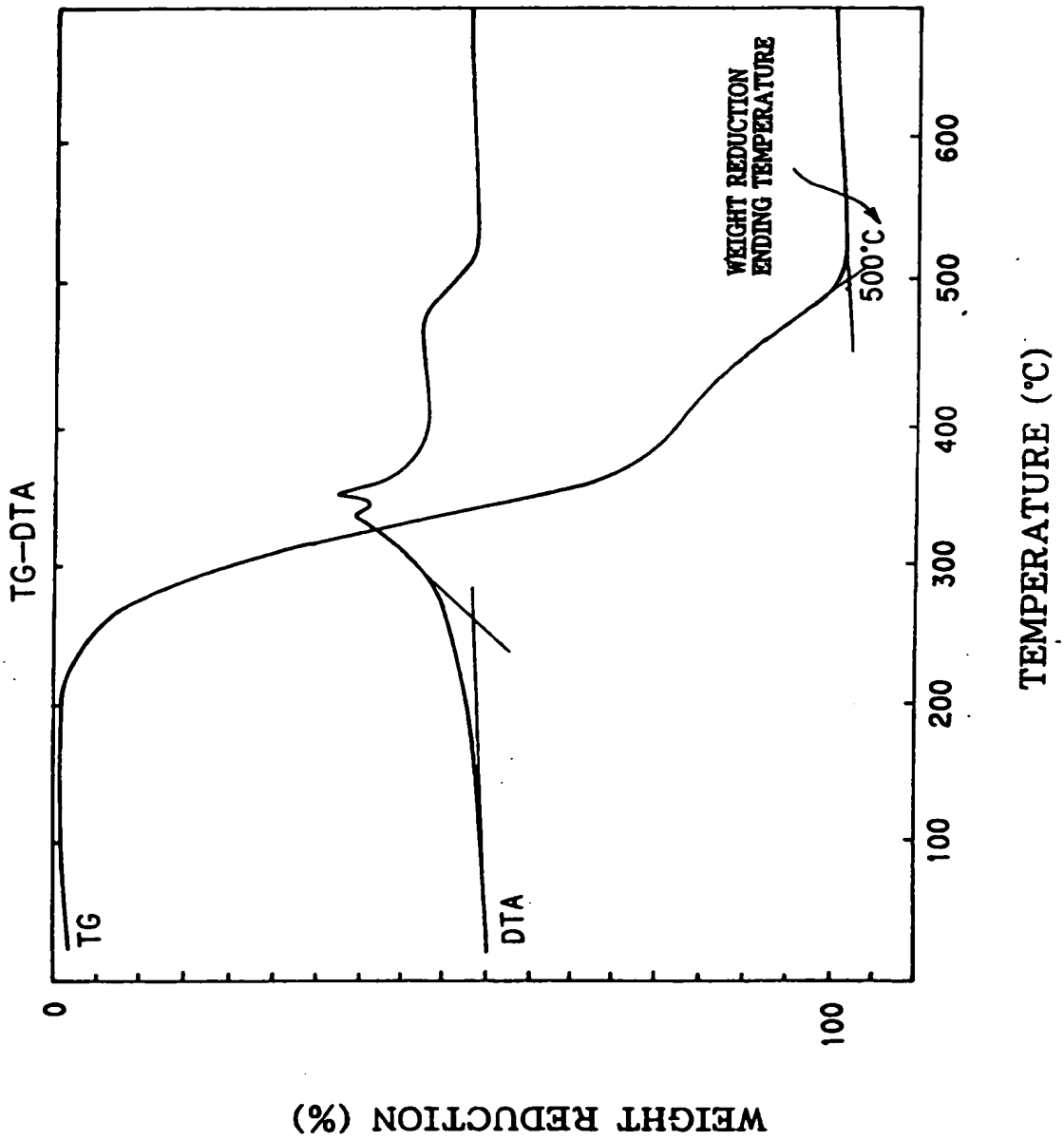
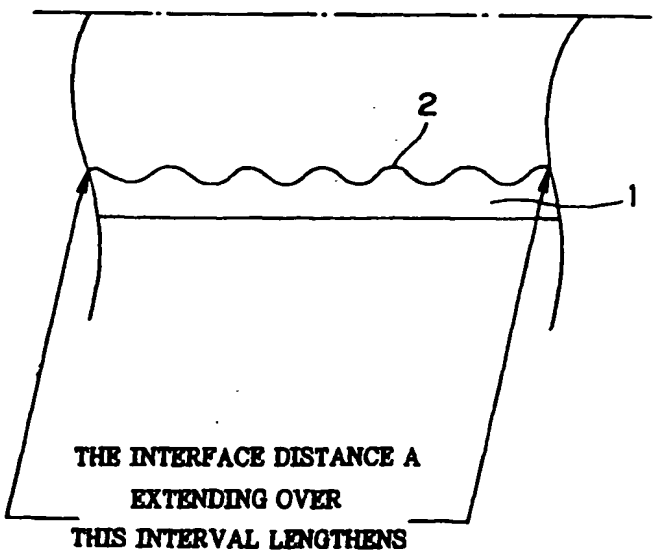


Fig.4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(11) EP 0 916 500 A3

(12) EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
29.12.1999 Bulletin 1999/52

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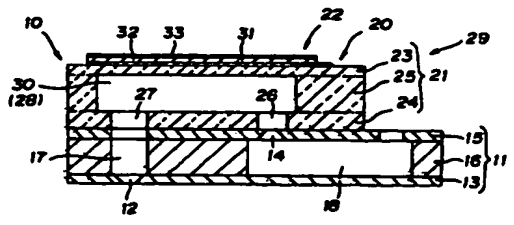
Fig.1



EP 0 916 500 A3

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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 9372

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	9 November 1999	Rivero, C

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